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Nematodes and Acanthocephalans of Raccoons (*Procyon lotor*), with a New Geographical Record for *Centrorhynchus conspectus* (Acanthocephala) in South Carolina, U.S.A.

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ABSTRACT: From April 1997 through April 1998, 128 raccoons (*Procyon lotor* (Linnaeus)) collected from 7 sites representing 4 physiographic areas in South Carolina were examined for gastrointestinal helminth parasites. Four species of nematodes (*Gnathostoma procyonis* (Chandler), *Physaloptera rara* Hall and Wigdor, *Arthrocephalus lotoris* (Schwartz), and *Molineus barbatus* Chandler) and 2 species of acanthocephalans (*Macracanthorhynchus ingens* (von Linstow) and *Centrorhynchus conspectus* Van Cleave and Pratt) were collected. The finding of 11 immature *C. conspectus* in 3 South Carolina raccoons represents a new geographical record for this species.

KEY WORDS: *Centrorhynchus conspectus,* raccoon, *Procyon lotor,* Nematoda, Acanthocephala, helminths, *Gnathostoma procyonis, Physaloptera rara, Arthrocephalus lotoris, Molineus barbatus, Macracanthorhynchus ingens,* South Carolina, U.S.A.

The raccoon (*Procyon lotor* (Linnaeus, 1758)) is an omnivore that ranges over most of North America and occurs in both rural and urban settings. Consequently, the range of zoonoses for raccoons is important in assessing risk to humans and domestic animals. In South Carolina, only limited studies on helminth parasites of raccoons have been reported previously (Harkema and Miller, 1964; Stansell, 1974). More recent reports of serious human illnesses from the northern and midwestern United States, such as cerebrospinal nematodiasis because of infection with the gastrointestinal nematode *Baylisascaris procyonis* (Stefanski and Zarnowski, 1951), led to the current study, which includes raccoons collected statewide from a wide variety of habitats (e.g., mountains, farms, urban areas, beaches, swamps, and barrier islands), allowing for a comparison of parasite burdens and consideration of human health risks associated with these parasites (Williams et al., 1997; Boschetti and Kasznica, 1995).

Materials and Materials

Raccoons (n = 128) were collected between April 1997 and April 1998 with foot-hold traps or wire live-traps. Traps were set at 7 sites that included 4 of the 5 physiographic areas of South Carolina. Site 1 included both urban and waterfowl management areas (WMA) in Pickens County (Foothills); Site 2 was a WMA in Union County (Piedmont); Site 3 was inland farm areas of Horry County (Lower Coastal Plains North, LCPN); Site 4 included both beach and wooded habitats in the tourist area of Myrtle Beach, Horry County (LCPN); Site 5 was a swamp located on the Savannah River in Hampton County (Lower Coastal Plains South, LCPS); and Sites 6 and 7 were both on barrier islands located in Charleston County (LCPS). John's Island (Site 6), next to and continuous with the mainland at times of low tide, is primarily forest and farmland with many freshwater ponds, whereas Seabrook Island (Site 7) is a small residential island about 1.5 km offshore, which lacks freshwater habitats. Each raccoon was subjected to multiple evaluations, which included not only our study of gastrointestinal helminth parasites, but also seroprevalence, culture and DNA studies for *Trypanosoma cruzi,* and museum study specimens. In addition, most animals were included in a trap-type capture effectiveness study conducted by the South Carolina Department of Natural Resources (SCDNR).

Raccoons were either euthanized by intramuscular injection of 0.2 ml/kg ketamine/xylazine followed by intraperitoneal injection of 1 ml/kg sodium pentobarbital, or were hunter-shot. Stomach and intestines from each animal were examined as soon as possible after death (within 1–2 hr). However, animals from 2 of the physiographic regions (Sites 3–7) were frozen at −4°C for 1–3 mo prior to examination for helminths because of the use of the animals for a trap-type study conducted by the International Association of Fish and Wildlife Agencies. Therefore, trematodes and cestodes were excluded from the overall analyses because freezing of a large number of hosts resulted in difficult collection and unreliable identification of flatworms.

All nematodes collected from the stomachs and small intestines of raccoons were preserved and stored in a 70% ethanol–5% glycerine solution. Representative specimens of each nematode were mounted in glycerine jelly. Acanthocephalans collected from the small

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intestine were placed in water until the proboscis everted, preserved in acetic acid-formalin-alcohol (AFA), and stored in 70% ethanol. Temporary wet mounts and permanent Mayer's acid carmine-stained mounts in Canada balsam were made for identification. Voucher specimens deposited at the U.S. National Parasite Collection in Beltsville, Maryland, have been assigned USNPC accession numbers 87838–87843. Fisher's exact test was used to detect significant differences ($P < 0.05$) in helminth prevalence (%) between study sites. Two-thirds of the animals caught were male, and 85% of all animals were mature. Because of the large bias toward males and adults, no statistical analyses were performed.

Results and Discussion

Of the 128 raccoons examined, 103 (80%) were infected with 1 or more of the 4 nematodes and 2 acanthocephalans listed in Table 1. *Gnathostoma procyonis* Chandler, 1942, and *Physaloptera rara* Hall and Wigdor, 1918, were recovered primarily from the stomach. *Arthrocephalus* (=*Placoconus*) *lotoris* (Schwartz, 1925) and *Molineus barbatus* Chandler, 1942, were collected from the posterior and anterior ends of the small intestine, respectively. Both *Macracanthorhynchus ingens* (von Linstow, 1879) and *Centrorhynchus conspectus* Van Cleave and Pratt, 1940, were recovered exclusively from the small intestine. Interestingly, 96.1% of raccoons examined from Sites 1–6 were infected with at least 1 helminth species, whereas only 5 of 26 (19.2%) raccoons examined from Seabrook Island (Site 7) were infected.

Gnathostoma procyonis, a stomach nematode that forms large nodules in the mucosa, was found at Sites 3 and 5 in significantly larger numbers than at other sites (Table 1). Extensive freshwater habitats were present at both sites, providing a favorable environment for the required first intermediate host, which is 1 of several species of cyclopoid copepods (Miyazaki, 1960). In contrast, no infections of *G. procyonis* were observed at 2 coastal locations (Sites 4 and 7), which lacked permanent freshwater habitats.

Physaloptera rara, a spirurid nematode recovered from both the stomach and small intestine of hosts, does not require the presence of freshwater habitats, because raccoons become infected by ingestion of various terrestrial arthropods (e.g., *Gryllus pennsylvanicus* Burmeister, 1838, Pennsylvania field cricket; *Blattella germanica* (Linnaeus, 1767), German cockroach; and *Centophiles* spp., camel crickets) (Lincoln and Anderson, 1973). Compared to all other sites, a sig-

Table 1. Summary data of nematodes and acanthocephalans from 128 raccoons, *Procyon lotor,* collected in South Carolina from April 1997 through April 1998.

Species of parasite	Site in host*	Within-area numbers of hosts infected (%)							State-wide	Intensity	
		Site 1 $n = 25$	Site 2 $n = 5$	Site 3 $n = 14$	Site 4 $n = 12$	Site 5 $n = 35$	Site 6 $n = 11$	Site 7 $n = 26$	$n = 128$	Mean ± SE	Range
Nematoda											
Gnathostoma procyonis	S	4 (15)	2 (40)	11 (79)	0 (0)	29 (83)	6 (55)	0 (0)	52 (41)	4.2 ± 0.51	1–17
Physaloptera rara	S, SI	20 (80)	0 (0)	1 (7)	1 (8)	25 (71)	2 (18)	0 (0)	49 (38)	38.7 ± 5.7	1–156
Arthrocephalus lotoris	SI, LI	15 (60)	2 (40)	3 (21)	3 (25)	7 (20)	5 (45)	1 (4)	36 (28)	19.9 ± 3.6	1–84
Molineus barbatus	SI	8 (32)	0 (0)	1 (7)	2 (17)	4 (11)	1 (9)	0 (0)	16 (13)	23.6 ± 6.9	1–94
Acanthocephala											
Macracanthorhynchus ingens	SI	12 (46)	1 (20)	9 (64)	8 (67)	28 (80)	6 (55)	4 (17)	68 (53)	9.7 ± 1.3	1–43
Centrorhynchus conspectus	SI	0 (0)	0 (0)	2 (14)	0 (0)	0 (0)	1 (9)	0 (0)	3 (2)	3.7 ± 2.7	1–9

* S, stomach; SI, small intestine; LI, large intestine.

nificantly higher prevalence of *P. rara* was observed in raccoons trapped at Site 1, with urban-captured animals dominating the number of infected animals. Because broad host specificity has been documented for physalopteroids, domesticated animals could accumulate large numbers of these worms by ingesting an infected intermediate host that commonly occurs in urban settings (Morgan, 1941).

High prevalences of both the raccoon hookworm, *A. lotoris,* and the trichostrongylid, *M. barbatus,* frequently have been reported in previous surveys (Harkema and Miller, 1964; Cole and Shoop, 1987). In the present study, however, overall prevalence of *A. lotoris* and *M. barbatus* was 28.1 and 12.5%, respectively (Table 1). Data from Seabrook Island are consistent with those of Harkema and Miller (1962), who previously reported an almost complete absence of *A. lotoris* and *M. barbatus* from Cape Island, South Carolina. These investigators suggested that the low prevalence of these 2 nematodes on coastal islands was due possibly to the detrimental effect of high tides, salinity of soil, and dry habitats on the free-living larval stages of these helminths. Additionally, seasonal variations have been documented, with lower prevalence during winter months (Smith et al., 1985), which could have contributed to the lower numbers observed in the current survey.

Although *B. procyonis* was not collected from any raccoon examined in this study, surveillance for this parasite should be continued because of its medical and veterinary significance and its reported widespread distribution in the United States (Kazacos and Boyce, 1989). Based on reports from southeastern states, Jones and McGinnes (1983) suggested that *B. procyonis* was found primarily in the more mountainous regions. The northwestern range of our study site, although classified as "Foothills," is not truly mountainous, which might account for the lack of *B. procyonis.* In contrast, however, *B. procyonis* recently was found in 70% of 33 raccoons examined in southern coastal Texas (Kerr et al., 1997). These investigators suggested that the nematode could have been acquired by ingestion of larvae in migratory wild birds, introduced from infected translocated raccoons, or the result of a northern expansion from Latin America. This recent finding of *B. procyonis* in southern Texas and limited reports from the adjacent state of Georgia (only 2 reports, each of a single infected raccoon [Babero and Shepperson, 1958; Kazacos and Boyce, 1989]) suggests the possibility of introduction of this nematode into South Carolina.

The most prevalent parasite collected was the acanthocephalan *M. ingens.* Infections occurred in raccoons from all study sites, with an overall prevalence of 53%. Although not considered a threat to public health, *M. ingens* infection in humans has been reported (Dingley and Beaver, 1985).

Six species of the acanthocephalan genus *Centrorhynchus* have been reported from North American birds of prey; however, little is known about the life cycle, geographical distribution, or prevalence of these acanthocephalan species. Read (1950) demonstrated experimentally that *Centrorhynchus spinosus* (Kaiser, 1893) was capable of developing to adults in laboratory rats, suggesting that members of this genus have the ability to complete development not only in bird definitive hosts, but also in mammalian hosts. One raccoon from John's Island (Site 6) and 2 raccoons from the Horry County inland site (Site 3) were infected with immature *C. conspectus.* Prior to the current study, immature forms of *C. conspectus* had been reported from 26 mammals representing 6 host species (3 *Didelphis virginiana* Kerr, 1792, Virginia opossum; 3 *P. lotor,* raccoon; 17 *Mustela vison* Schreber, 1775, mink; 1 *Spilogale putorius* (Linnaeus, 1758), spotted skunk; 1 *Blarina brevicauda* Gray, 1838, short-tailed shrew; and 1 *Urocyon cinereoargenteus* Schreber, 1775, gray fox) from 5 states (Virginia, Arkansas, North Carolina, Ohio, and Florida) (Nickol, 1969; see Richardson and Nickol, 1995). The largest number of worms previously reported from any individual mammalian host was 2 worms, whereas 1 raccoon in the current survey from the inland Horry County site (Site 3) was infected with 9 *C. conspectus* (see Richardson and Nickol, 1995). Several owl species, including *Bubo virginianus* (Gmelin, 1788), the great horned owl; *Otus asio* (Linnaeus, 1758), the eastern screech owl; and *Strix varia* Barton, 1799, the barred owl, have been reported as definitive hosts for *C. conspectus* (Richardson and Nickol, 1995). No intermediate host has been identified, although cystacanths of *C. conspectus* have been found in paratenic hosts (*Nerodia sipedon* (Linnaeus, 1758), the water snake, from North Carolina; *Rana clamitans* Latreille, 1801, the aquatic green frog, from Virginia; and *Des-*

mognathus fuscus (Green, 1818), the northern dusky salamander and *Plethodon glutinosus* (Green, 1818), the slimy salamander from Louisiana) (Nickol, 1969; see Richardson and Nickol, 1995). The finding of 11 immature *C. conspectus* in 3 South Carolina raccoons represents a new geographical record for this species. The collection only of immature *C. conspectus* from raccoons in this study supports earlier reports that suggested that wild mammals are aberrant hosts for this parasite (Richardson, 1993).

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